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# DISCUSSION OF THE OKLAHOMA STATE UNIVERSITY ACTIVE TEMPERATURE CONTROL SYSTEM


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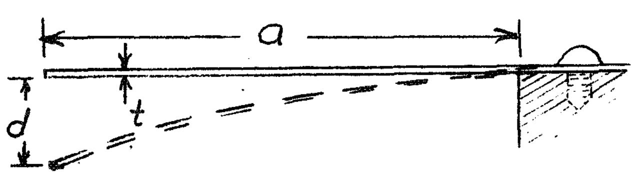
This discussion summarizes the work done under NASA Grant NsG-454 at Oklahoma State University as described in the Semi-Annual Report "Spacecraft Temperature Control by Thermostatic Fins" by J. A. Wiebelt and J. F. Parmer. A very interesting and potentially useful active temperature control device is being developed (see Figure 1). It consists of pairs of bimetallic strips mounted back-to-back. At a specified temperature (say $100^{\circ}F$) the bimetallic strips are straight and perpendicular to the mounting surface. If the mounting surface, which represents the skin or radiating surface of a spacecraft, is painted white and the bimetallic surfaces are coated with a highly reflecting material such as evaporated aluminum, the vertical position would have the highest effective emittance. When the temperature is less than the temperature corresponding to the vertical position the adjacent bimetallic elements bend away from each other and reduce the effective emittance of the total surface.

The bimetallic material chosen for analysis and fabrication of an experimental unit is Truflex P-675R manufactured by the Metals and Controls Division of Texas Instruments, Inc. The deflection equation is as follows:




$$d = 113 \times 10^{-7} (\Delta T) \frac{a^2}{t}$$

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From Figure 2 it can be seen that sunlight incident on the grooves may strike the base directly or it may be reflected from the walls one or more times before striking the base. Each time a ray of sunlight strikes the walls, part of its energy is absorbed and the rest is reflected specularly. When a ray strikes the base, part of the energy is absorbed and the rest is reflected diffusively. Part of the diffusively reflected energy escapes directly through the groove opening and the rest is partially absorbed and reflected specularly by one or more collisions with the groove walls before escaping. Obviously, a great deal of effort is required to trace the history of each ray of sunlight in order to arrive at a value of effective solar reflectance. The details of this analysis are described in the semi-annual report. The results are summarized in Figures 3, 4, and 5. (All Figures are taken directly from the semi-annual report) The curves are plotted showing the ratio of effective reflectance to base reflectance as a function of solar polar angle, with wall reflectance as a parameter. As one might expect the effective reflectance falls off rapidly as the solar polar angle approaches $90^{\circ}$, increases with increase in wall reflectance and decreases with increase in a/b, a measure of the effective depth of the grooves.

## Wavelength Dependence of Effective Reflectance

Since the effective reflectance is a function of both wall and base reflectances, one specular and the other diffuse, it can be expected to vary with wavelength. To obtain the effective solar reflectance it is necessary to integrate over the solar spectrum the effective spectral reflectances weighted by the relative solar intensity at each wavelength interval. Figure 6 shows the reflectances of evaporated aluminum, a white paint, and the effective reflectances of the combination as a function of wavelength. The integrated values are shown in Figure 7.

## Heat Dissipation Characteristics

An analysis was made to determine the net heat flux from the surface. The following assumptions were made:

1. Fins are vertical and specular;
2. The base is horizontal and diffuse;
3. Fins are infinitely long;
4. Conduction between fins and base is negligible;
5. Fin and base temperatures are equal;
6. Emittance and solar absorptance values for the groove are determined for the vertical position and are assumed to be independent of temperature;
7. Emittance and solar absorptance of the slit = 1.0 and are independent of temperature; and
8. The relative surface areas of grooves and slits are determined from the deflection equation for the fin material.

In the analysis of solar reflectance, only the vertical position for the fins was considered. If the deflection of the fins from the vertical position is small, the values of emittance and solar absorptance are reasonably accurate for positions other than the vertical position. As the fins separate slightly, a V-shaped slit opens between adjacent fins. For small deflections this slit can be assumed to be optically black even though the surfaces are highly reflective. As the deflection increases significantly from the vertical position the error increases appreciably. The groove takes on the properties of a cavity and the slit becomes more reflective.

In Figures 8 and 9, net heat flux is plotted as a function of solar polar angle, with fin temperature as a parameter. The solutions for temperatures near 110$^{\circ}$F, the vertical position, are reasonably accurate. Figures 10 and 11 show surface temperature as a function of solar polar angle for a fixed internal heat dissipation of 37.5 BTU/Hr.-Ft.$^2$. Again the curves are reasonably accurate for temperatures near 110$^{\circ}$F.

These curves indicate that the surface temperature is constant over a fairly wide range of solar polar angles. This is the result of a decrease in reflectance or an increase in absorptance with solar polar angle as shown in Figure 7 combined with the decrease in incident solar flux with solar polar angle.

## Future Plans (Proposed)

Oklahoma State University has proposed to extend the analysis by: (1) Removing the restriction that the fins be vertical in determining effective reflectance, (2) considering fins of finite length, and (3) allowing for conduction between the fins and the base. In addition, an experimental unit would be fabricated and tested under solar simulation. Goddard would provide the solar simulation facilities.

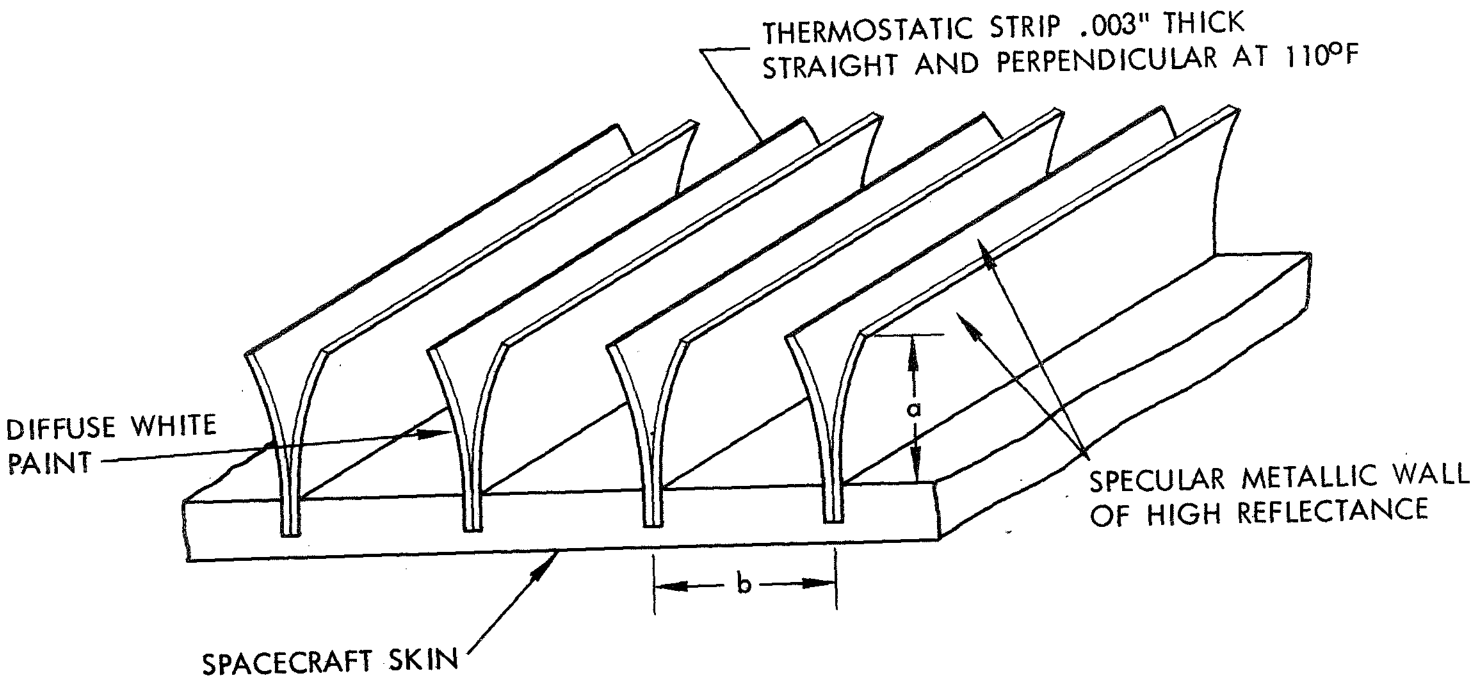


Figure 1. Thermostat surface

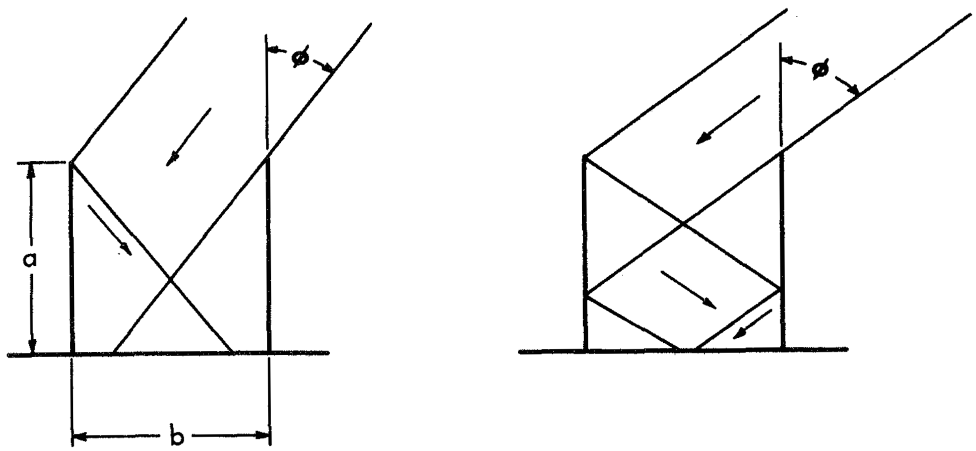


Figure 2. Multiple reflections of solar illumination

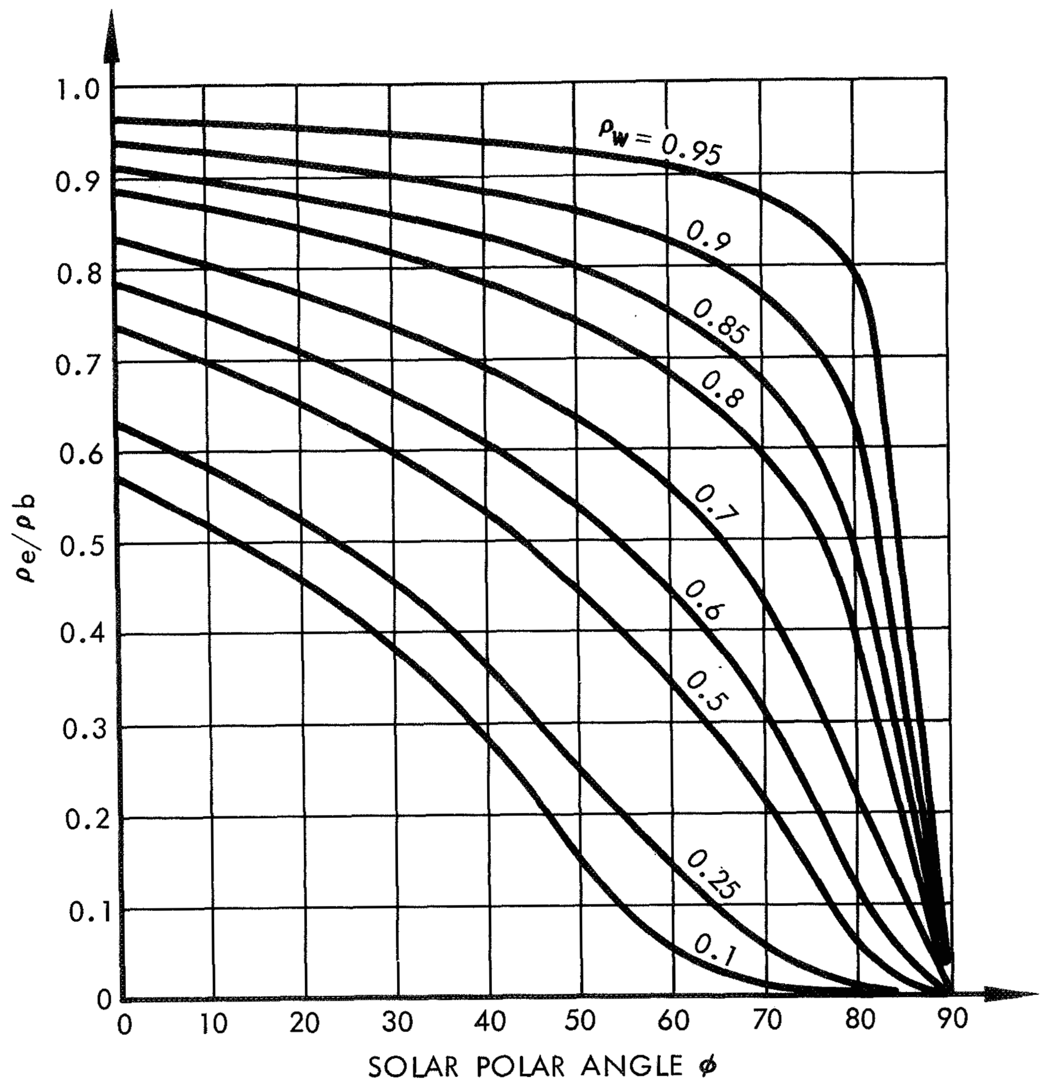


Figure 3. Effective reflectance ratio, a/b = 2/3

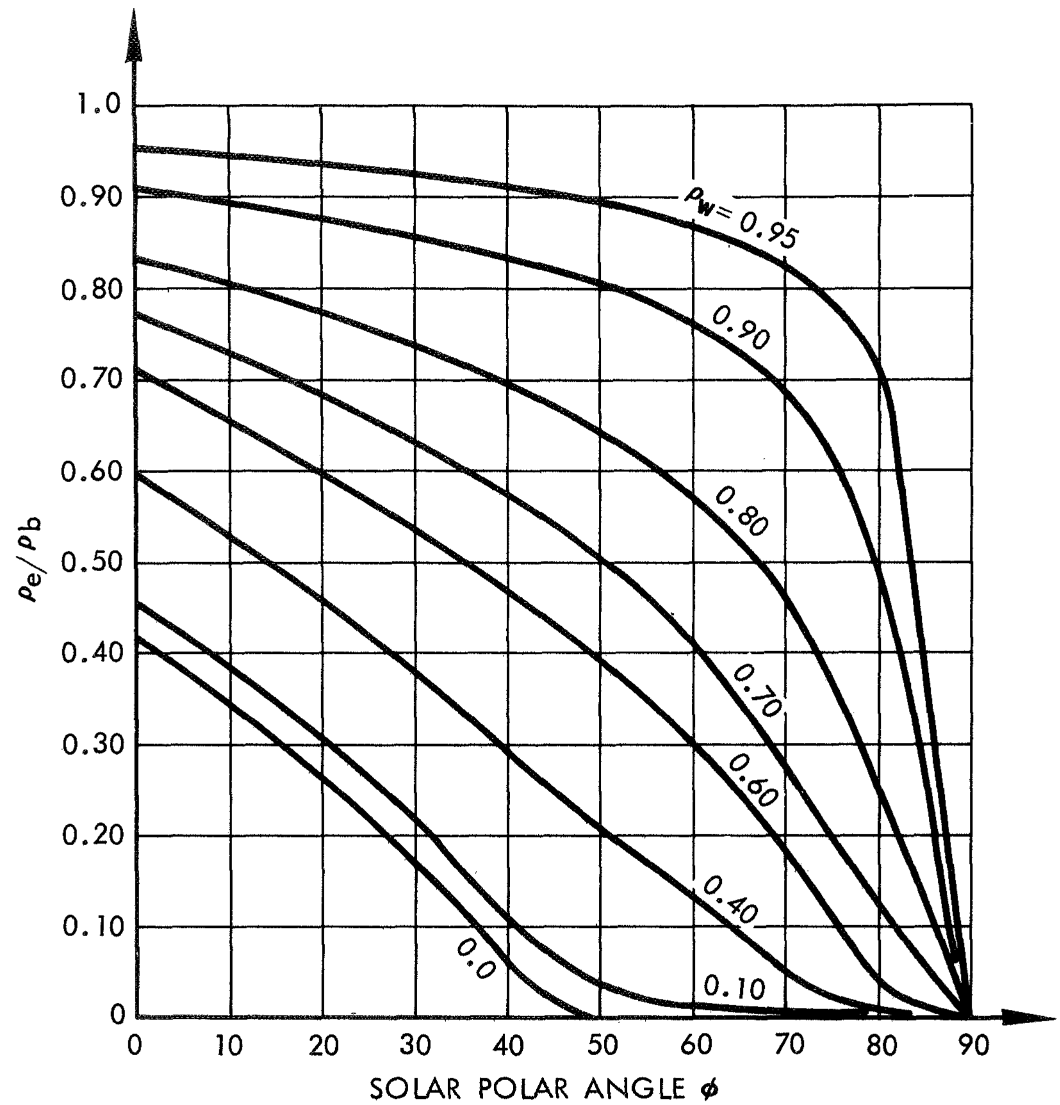


Figure 4. Effective reflectance ratio, a/b = 1

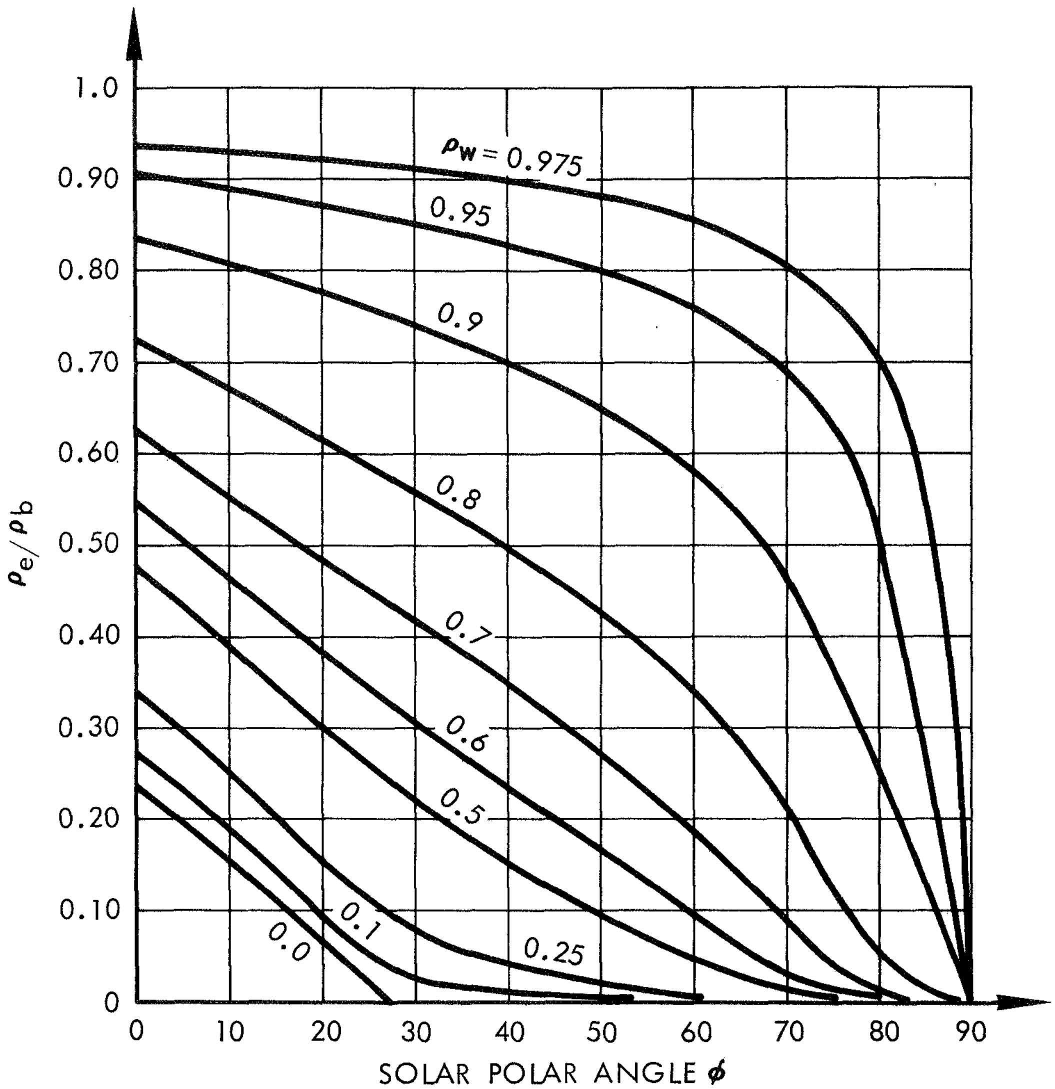


Figure 5. Effective reflectance ratio, a/b = 2

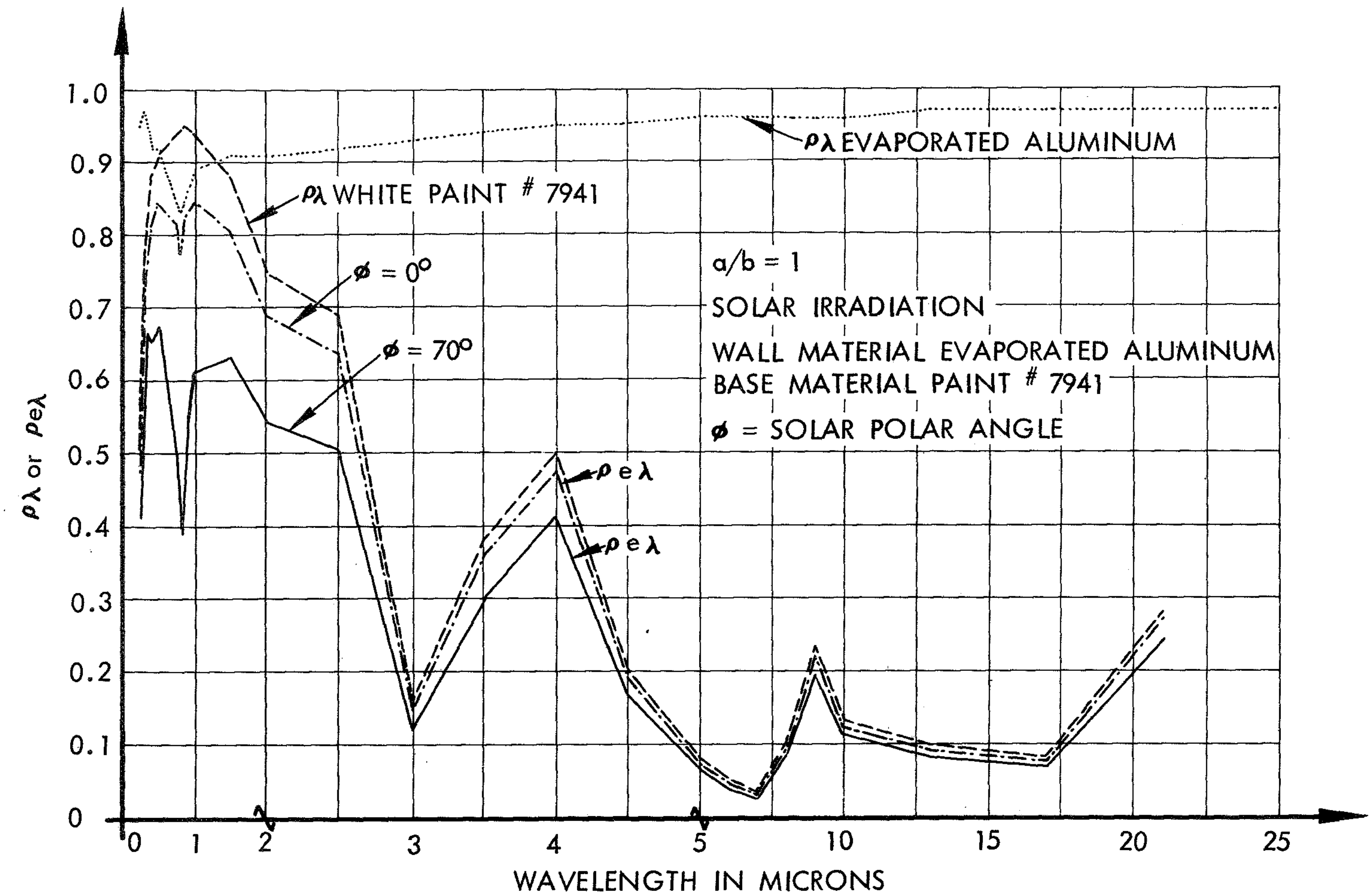


Figure 6. Effective monochromatic reflectance

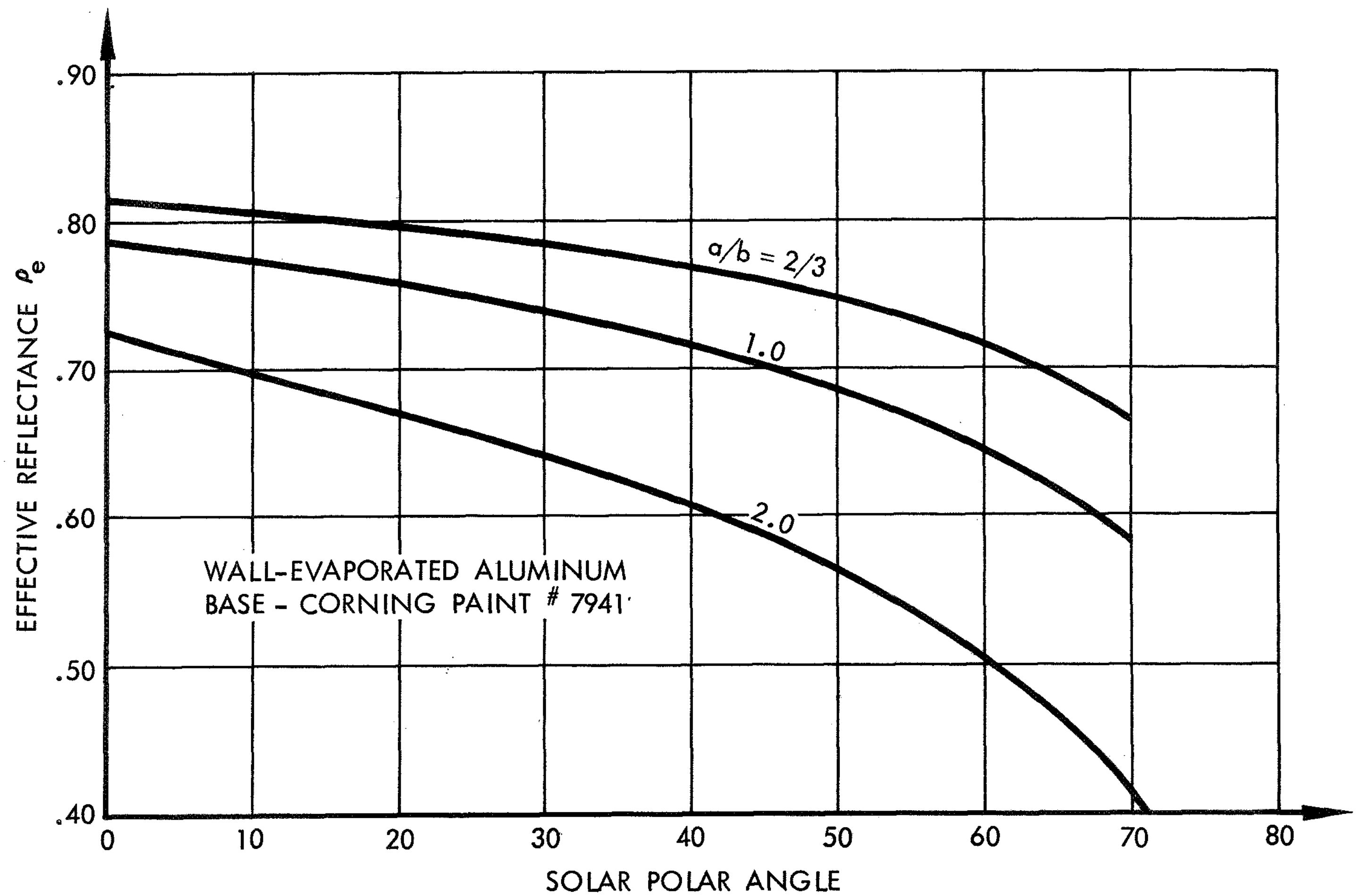


Figure 7. Effective reflectance

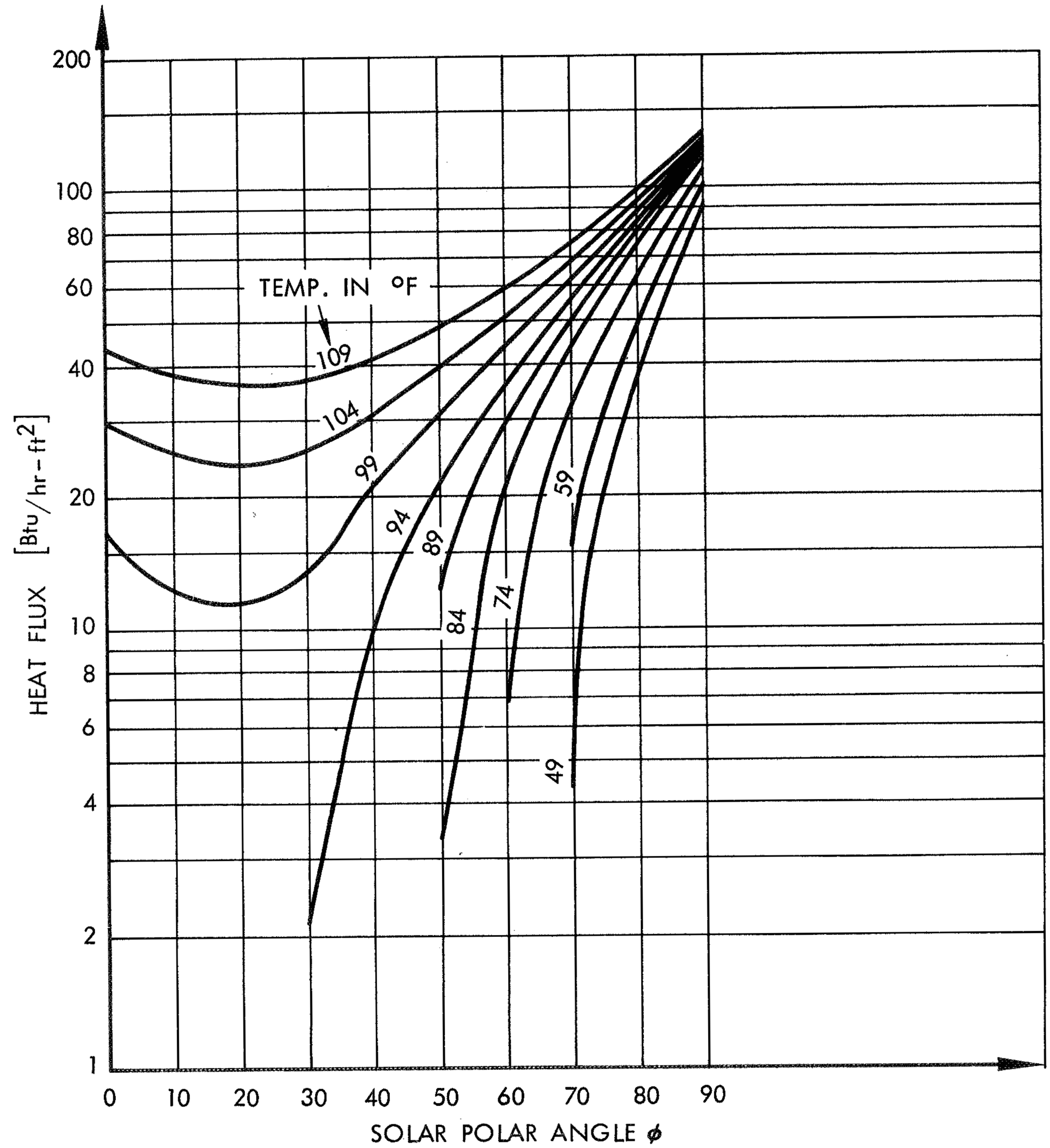


Figure 8. Equilibrium temperatures for a .75" x .75" thermostat surface

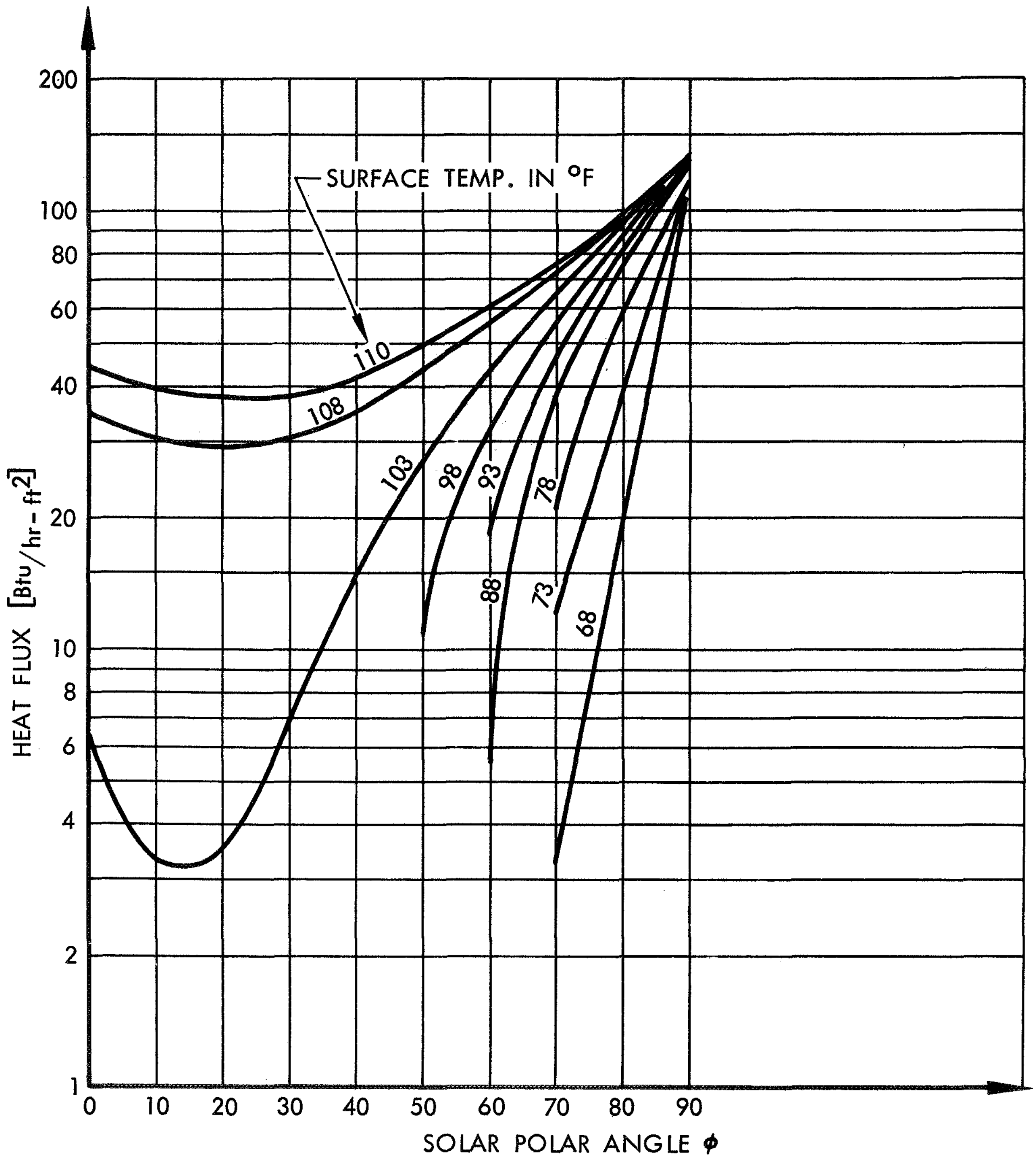


Figure 9. Equilibrium temperatures for a 2" x 2" thermostat surface

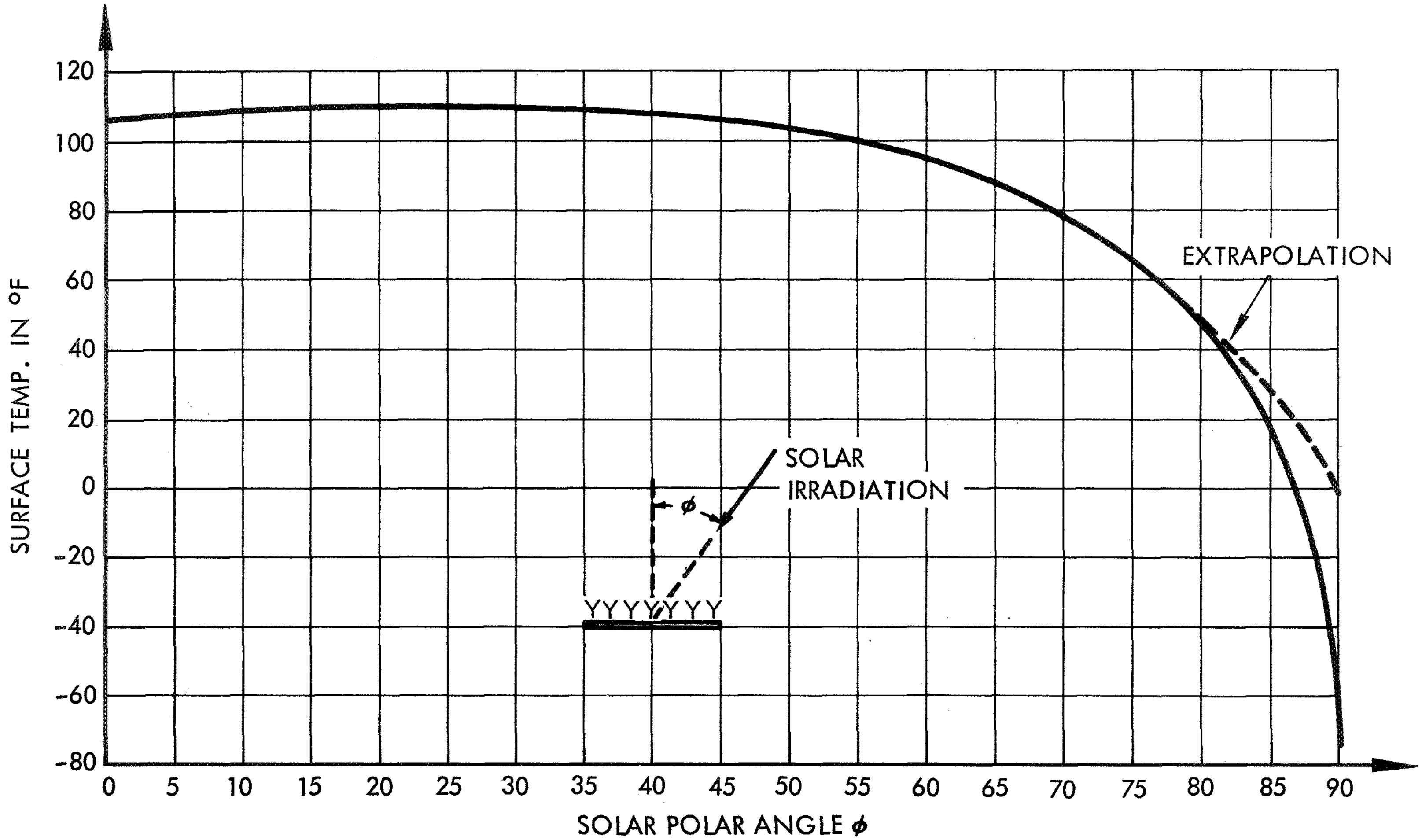


Figure 10. Surface temperature of a thermostat surface with fin height (a) of 0.75 inches, fin spacing (b) of 0.75 inches with internal heat generation of the spacecraft such that 37.5 $^{\mathrm{Btu}}/_{\mathrm{hr-ft}^2}$ must be radiated to space.

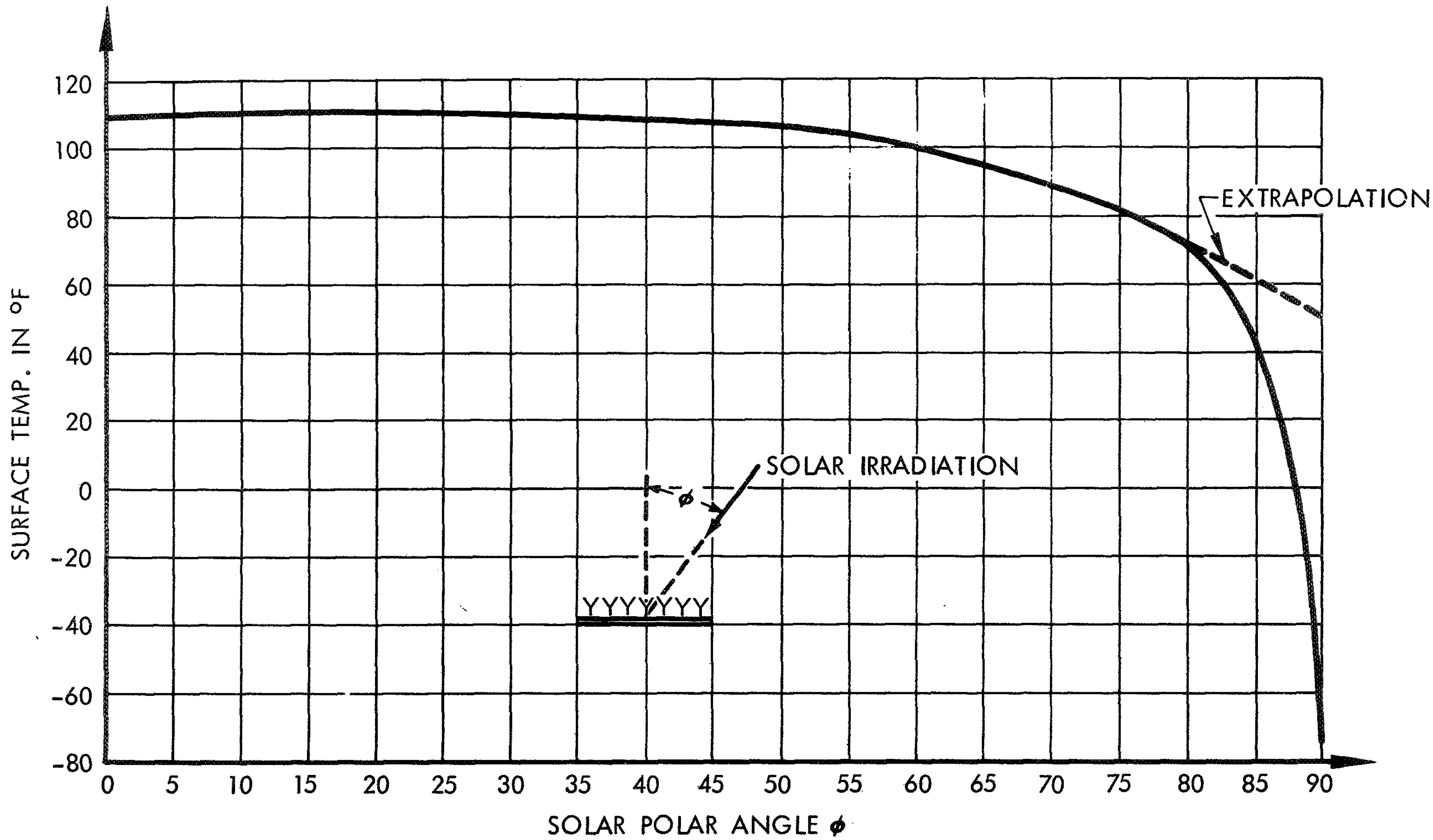


Figure 11. Surface temperature of a thermostat surface with fin height (a) of 2.0 inches, fin spacing (b) 2.0 inches with internal heat generation of the spacecraft such that 37.5 $^{Btu}/hr-ft^2$ must be radiated to space.